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ABSTRACT

This paper describes a study that was undertaken at the University of Illinois at Urbana-Champaign to compare the databases selected by 75 inexperienced student online searchers aided by an existing gateway system--INFOMASTER, a version of EASYNET--with databases selected manually by four experienced searchers who were reference librarians from four departmental libraries. The online searches were done in response to patron requests in the university library, and the topics searched were the same for both groups. The database selections of the librarians were then compared with the selections made by students using INFOMASTER to investigate the hypothesis of this research, i.e., the inexperienced searchers aided by the gateway would do as well as the experienced professional searchers in selecting databases likely to be the most productive in their yield of potentially relevant items. The comparison shows that database selection by INFOMASTER still depends heavily on human judgments, especially in the selection by searchers of the subject field in which a query falls. Suggestions for improving automated database selection systems with artificial intelligence techniques conclude the report. Appended are five tables displaying statistics and results of data analyses together with an example of database postings. (8 references) (CGD)

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# AN EVALUATION OF A GATEWAY SYSTEM FOR AUTOMATED ONLINE DATABASE SELECTION

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Keywords: Online Systems, Interfaces, Gateways, Database Selection, Artificial Intelligence

Abstract: An evaluation of automated online database selection by an existing gateway system (INFOMASTER, a version of EASYNET) was performed at the University of Illinois at Urbana-Champaign. The results of automated database selection by INFOMASTER were compared with the databases selected manually by four experienced online reference librarians for the same queries. The comparison shows that database selection by INFOMASTER still heavily depends on human judgements, especially the selection by searchers of the subject field in which a query falls. INFOMASTER could select databases as well as human intermediaries when the gateway user properly selected the subject area for a particular query. Some suggestions for improving automated database selection by a gateway system with artificial intelligence techniques are outlined.

## 1. Introduction

The tremendous growth of computer-readable databases and online systems makes automated database selection very desirable in online services, especially as an aid to inexperienced searchers. Since the 1980s, various kinds of gateway systems (or interfaces, front-ends, and intermediary systems) have converted information among online systems and aided the users in various ways including database selection.[1-2] The research reported in this paper sought to determine the effectiveness, problems, and techniques of gateway systems for automated database selection through an evaluation of an existing gateway system (INFOMASTER of Western Union, which is based on EASYNET of Telebase Systems, Inc.) that includes the capability to select databases in online services.[3]

## 2. Hypothesis and Methodology

This study was conducted to compare the databases selected by inexperienced online searchers, aided by a particular gateway, with those chosen by experienced searchers performing online searches in response to patron requests in a university library. The topics for which the selections were made were the same for both groups.[4]

The study hypothesized that the inexperienced searchers aided by the gateway would do as well as the experienced professional searchers in selecting databases likely to be most productive in their yield of potentially relevant items. "Likely to be most productive" refers to probabilistic criteria - the more potentially relevant items the database contains, the greater the chance that some at least will be found when the database is searched online. In other words, this comparison was limited to a quantitative measure of search results from the databases selected by both groups.

The study was done at the University of Illinois at Urbana-Champaign from February through March of 1987. Seventy-five students in the Graduate School of Library and Information Science of the University of Illinois at Urbana-Champaign participated in this study. They had just started an online searching course at the end of January 1987 and had no prior online searching experience, so they were considered to be the "inexperienced searchers". Four professional online reference librarians from four departmental libraries (Engineering Library, Education and Social Sciences Library, Agriculture Library, and General Reference Library) participated in the study as the "experienced professional searchers", who had online searching experience of between two and six years. INFOMASTER, as a test gateway system selected for this study, provides access to over 800 databases on seventeen online systems, thus offering a wide subject area for the test of database selection. Fifty search queries

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were selected from the actual searches which had been conducted by the experienced searchers (librarians) from December 1986 through January 1987 in four departmental libraries. Data about these queries for online searching, such as search topic, type of document needed, the subject field, and the key words for the search topic, as well as a record of the database selected and the search strategy used, were provided by the librarians. Inexperienced searchers were given the information about the queries prior to logging on to INFOMASTER. Each student searched two different topics and each query was searched by three different students, so that there was a total of 150 searches done by seventy-five students searching fifty queries on INFOMASTER.

To effect the comparison of database selections, a Posting Database (PD) for each search query tested was established as the standard. The databases listed in the PD for each query were those that appeared to contain at least one potentially relevant item for the query. These databases were identified on the basis of the occurrence of topical keywords or phrases of the query in database indexes, either through DIALOG's DIALINDEX or through BRS's BRS/CROS, depending on which online system the librarian searched for a particular query because all fifty queries had been searched by librarians using only BRS or DIALOG. The search statement for each search topic used for establishing a PD was formulated by the researcher based on information supplied by the librarians (the same information supplied to the students). Only those keywords occurring in the title of the search were used. The number of items for each database in the PD should indicate the relative probability of locating potentially relevant items on the search topic in each database. When performing the comparisons of database selection by librarians and by INFOMASTER operated by students, the standard for numbers of items retrieved from the databases was based on the PD. (See APPENDIX: Example of Posting Databases (PD)) In this way, it was possible to avoid the problems caused by the fact that the students and the librarians would be searching at different times and with different search strategies. That is, if a database selected (by INFOMASTER or by the librarian) could be found in the PD for a particular query, the number of items considered to be retrieved from this database for the comparison was the number of items indicated in the PD for this database. If the database selected by INFOMASTER was not already in the PD, the database would be searched with the search strategy used for the PD of the corresponding query to establish the number of postings.

Since three students searched the same query using INFOMASTER, there were three possible cases for the consistency of database selection by INFOMASTER: (1) all three searches selected the same database for a particular query; (2) two searches had the same database selections but another was different; (3) three searches for the same query had all different databases selected. For the inconsistent cases of database selections, there would be three results (for case (2) above, only two results) based on the number of items retrieved from the three databases selected: best result, middle result, and worst result. In this study, only the best and worst gateway results were used to compare with those databases selected by the librarians. That means, it would test whether in the best result of database selection from INFOMASTER, the gateway (INFOMASTER) could (or couldn't) select the database for a particular query as well as the human intermediary; and whether in the worst result, INFOMASTER could (or couldn't) select the databases as well as human intermediaries.

## 3. Research Results

The 150 searches for fifty queries by seventy-five students (inexperienced searchers) through INFOMASTER used a total of six online systems accessible through INFOMASTER with twenty-four different databases selected for these queries. (For comparison, sixteen databases from two online systems (BRS & DIALOG) were used by librarians for these fifty queries). Among the six online systems involved, ninety-nine of 150 searches were conducted on DIALOG (66 percent of the total number of searches), twenty-eight on BRS (18.7 percent), thirteen on SDC (8.7 percent), five on Data-Star (3.3 percent), three on Pergamon InfoLine (2.0 percent) and two on WilsonLine (1.3 percent). DIALOG and BRS were the major online systems used in the INFOMASTER online network for these searches.

Statistical comparisons of database selections between librarians and INFOMASTER operated by students were conducted to investigate the hypothesis of this research. Two cases were analyzed: gateway best result and gateway worst result (as explained above) with results reported in Table 1. The gateway best result supported the hypothesis, i.e., in the gateway best result INFOMASTER could lead the inexperienced searchers to select databases as good as those selected by the librarians. But the result in the gateway worst case failed to support the hypothesis.

The consistency of database selections between librarians and INFOMASTER operated by students is detailed in Table 2. In the gateway best result, twenty-nine queries (consistency of 0.58) had the same databases selected by librarians and by INFOMASTER. Thirteen queries had the best databases as ranked by PD selected by INFOMASTER (but fourteen queries had the best databases as ranked by PD selected by librarians). Twenty-one queries had inconsistent database selections by librarians and INFOMASTER with the librarian making the better choice in thirteen cases and INFOMASTER making the better choice in eight. In the gateway worst result, twenty-eight queries had the same databases selected by librarians and INFOMASTER (consistency of 0.56). Only five queries had the best databases as ranked by PD selected by INFOMASTER (compared to fourteen for the librarians). For twenty of the twenty-two queries which had different database selections between the two groups, librarians selected the better databases.

The consistency of database selections by INFOMASTER for the same query among three students is shown in Table 3. Thirty-two queries (consistency of 0.64) had consistent database choices. Among those eighteen queries with inconsistent database selection from INFOMASTER, fifteen of them had two different choices and three had three choices.

In addition, the results of a questionnaire survey to the students who participated in this study are reported in Table 4, which can supplement the evaluation of INFOMASTER for database selection from the viewpoints of searchers. Most of the searchers (92 percent) felt that INFOMASTER was easy to use. Fifty-four of seventy-five searchers (72 percent) thought that INFOMASTER was helpful for database selections. Forty percent of searchers spent less than fifteen minutes for two searches in INFOMASTER (each search was limited to up to ten citations printed out). Fifty-two percent of searchers spent from sixteen to thirty minutes for two searches. Only six searchers spent over thirty minutes but no one spent over one hour.

## 4. Analysis of Database Selection by INFOMASTER

From searching INFOMASTER in this study, one can see that the procedures of automated database selection by INFOMASTER are through narrowing down the subject fields (usually less than six hierarchical subdivisions for a subject category) of a particular query based on the subject selection by a human searcher from a series of menus (including choosing a type of document after the most specific subject field is selected). The subject fields and the types of documents were categorized in a hierarchical structure designed by the INFOMASTER system. All subjects and types of documents selected by searchers must be within the hierarchical subject lists pre-organized by the system.

From the research results, when the subjects and types of documents selected by human searchers of INFOMASTER were the same as those selected by librarians, the databases selected by INFOMASTER could be as good as the librarian's but few could be better than the librarian's choices. When the subjects and types of documents selected by the searchers of INFOMASTER differed from the librarian's, INFOMASTER usually selected different databases, of which some might be better databases (when the subjects selected by INFOMASTER's searchers were better than the librarian's). Therefore, the subject selected by the human searcher is the key factor influencing database selection of INFOMASTER. That is, "automated" database selection by INFOMASTER actually still depends heavily on human judgement.

However, since all subjects selected by the searchers must be limited by the hierarchical lists of subject fields designed by INFOMASTER, the subject selections not only depend on human judgement but are also limited by INFOMASTER's system design for subject categories. Queries in interdisciplinary subjects, of which the subjects might not be covered in the subject lists of INFOMASTER for selections, proved very hard for searchers to select the suitable subjects. It is one of the important reasons leading to the worst results for database selection by INFOMASTER.

As for the consistency of database selections by INFOMASTER for the same query, it was also mainly influenced by the different subjects selected by different searchers of INFOMASTER. Table 3 shows the inconsistency of database selections for the same queries distributed by subject. The queries with low inconsistency of database selection are mostly those queries located in social sciences, education, or agriculture (0 or 18.2 percent).

The queries located in interdisciplinary areas such as materials science and environmental science had the highest inconsistency (87.5 or 100 percent) of database selections for the same query. It might be due to the

fact that most searchers of INFOMASTER in this study were graduate students in library school with a social sciences background, and were more familiar with those queries in social sciences than those in the sciences, especially those in interdisciplinary fields of sciences (i.e., materials science). Even when the subjects of queries had been provided by librarians as data about the queries given by the end users, still some students selected different subjects for those queries based on their own judgements or limited by the hierarchical subject lists for categories given by INFOMASTER. These categories were simple and mostly for discrete disciplines, but did not cover all detailed subdivisions, even excluding some categories in high class levels (such as no environmental science in the subject list from INFOMASTER).

But in some cases, the same subject selections from different searchers for the same query still led to inconsistent databases selected by INFOMASTER. This was apparently due to random selection from a group of databases for a particular subject by INFOMASTER. For instance, query 18 (of which the search topic is "Book Theft in European Libraries in the 18th and 19th Centuries") is a topic about library science. All three students selected the same subject (library science) as the librarian's subject selection. But INFOMASTER offered two different databases for three searches (two of these were the same (SOCIAL SCIENCES CITATION INDEX (SSCI)), the other one was a different one (INFORMATION SCIENCE ABSTRACTS (ISA))).

Even with the correct subject selection by the searchers, INFOMASTER's selection of the best database (ranked by PD) for a particular query would also depend on the random selection from a group of databases for a particular category selected by the system. For instance, query 18 mentioned above, had the same and correct subject selection as the librarian's (library science). But neither of the databases selected by INFOMASTER (ISA and SSCI) was as good as the librarian's (LISA) which was ranked as the best database for this query in its PD. There are two possible explanations for this kind of failure by INFOMASTER: (1) The INFOMASTER database selection actually only depends on the subject selection of a query but not the query itself. That is, INFOMASTER can not "think" as the human intermediary to seek information for a particular query in detail: which database is the "best" one to meet this specific query. In this way, INFOMASTER selects a database randomly among a group of databases only according to the last subject field and type of document selected by the searcher for a query, and does not take the search topic into account. Two tests confirmed this in the study. The last subject category selected for both test searches was Education, with the type of document as "Professional Journals". At the first time the topic input was "Surge Protect/ and Microcomputer", a topic about computer science rather than education. The database selected by INFOMASTER was ERIC. The second time the topic input was a group of "garbage symbols" such as "SALDJFLALE/ AND 88JDKE", but the database selected by INFOMASTER was still ERIC. It seems that the search statements did not influence database selection by INFOMASTER at all. (2) Commercial considerations may be another factor influencing INFOMASTER in selection of databases. For instance, when query 18 (mentioned above, about library science) was searched, the system asked, "This database carries a surcharge. Do you wish to continue?"; it then picked SSCI as the database selected which was not actually the best database for this particular query. If commercial considerations influence database selection, the database chosen may not be the best choice in terms of highest postings.

These two reasons (for influencing the best databases selected by INFOMASTER) also could be considered to be the factors influencing the consistency of databases selected by INFOMASTER for the same query in different searches by INFOMASTER. Random selection from a group of databases can lead to different databases for even the same query as long as the same subject and type of document were selected.

## 5. Conclusion and Suggestions

Automated database selection by a gateway system among online networks is necessary and possible for online services. The major technique for "automated database selection" by INFOMASTER is through narrowing down the subject selections for a particular query using menu choices by the human searcher, then, selecting a database seemingly at random from among a group of databases for the queries falling in a particular subject field. That is, AI techniques are applied in only a limited way to the database selection by INFOMASTER. Therefore, automated database selection can be termed a "system component" [5] in a "synthetic intelligent system", which is the synthesis of man and machine but not a replacement of man by machine.[6]

There are several problems in database selection by a gateway system found in this study, which could be improved with some AI (artificial intelligence) techniques, as follows:

1. There should be some "Machine Learning" functions for automated database selection by a gateway system. Machine Learning is "to study computational methods for acquiring new knowledge, new skills, and

new ways to organize existing knowledge".[7] In information retrieval, learning functions are to modify the system response during the processing of a particular query in order to retrieve items most likely to meet the needs of the searcher, or, to improve system response over time.[8] When a database selected by the gateway system is not satisfactory (or not available for access in the meantime because of some system problems), the system should be able to change to other suitable databases (or online system) to process searches. But INFOMASTER could not change its selection of database and online system besides the first choice as long as the same subject field and the type of document were selected, unless the searchers returned at a later time when the random selection of databases from INFOMASTER has been changed.

2. As mentioned above, the hierarchical subject structure designed by INFOMASTER should be implemented or use some implemented methods (such as coordinating subject terms) to make the subjects listed for selections have more categories (including some more subdivisions and interdisciplinary fields) or be more flexible to meet queries.

3. More AI techniques (such as heuristics, machine learning, natural language processing) should be applied for automated database selections by a gateway. That means that more decisions should be by machine rather than depending on human searchers, such as increasing machine judgements instead of the subject selections from human searchers' judgements as much as possible.

4. Database selection by the gateway system should focus more on the subject of the search query itself instead of being based on the wide subject field in which the query falls. That means, within the subject field of queries, the details of the query should be taken into account for the BEST database selection.

Many of these suggestions are potentially worthwhile areas for research. But it also can be considered to be the trend of gateways for automated database selection in online services in the future.

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**Table 1. Statistical Results for Comparisons of Database Selection Between Librarians and INFOMASTER Operated by Students**
(With Chi-Square Statistical Method)

For the comparison of performances between the two approaches (Librarian vs. INFOMASTER), there were three outcomes: same, librarian better choice of databases, and INFOMASTER better choices of databases, which are listed in the table as **Same**, **Better** (Librarian or INFOMASTER), **Poorer** (Librarian or INFOMASTER).

**Hypothesis (H0):** The performance of INFOMASTER for database selections is the same as librarians' (at the significance level 0.05).
That is, INFOMASTER can select appropriate databases as well as the librarians.

| Cases | | Same | Better | Poorer | Critical Value | $X^2$ Value | df Value | Result |
|---|---|---|---|---|---|---|---|---|
| Best Gateway Result | Librarian | 29 | 13 | 8 | 5.99 | 2.38 | 2 | Support $H_0$ |
| | INFOMASTER | 29 | 8 | 13 | | | | |
| | Total Number | 29 | 21 | 21 | | | | |
| Worst Gateway Result | Librarian | 28 | 20 | 2 | 5.99 | 29.45 | 2 | Reject $H_0$ |
| | INFOMASTER | 28 | 2 | 20 | | | | |
| | Total Number | 28 | 22 | 22 | | | | |

**Table 2. Categories of Consistency in Database Selection Between Librarians and INFOMASTER Operated by Students**

Notes:
**Category I** : Librarian and INFOMASTER made the same choice, and the choice is the best database ranked in PD;
**Category II** : Librarian and INFOMASTER made the same choice, but the choice is NOT the best database ranked in PD;
**Category III** : Librarian made better choice than INFOMASTER did.
**Category IV** : INFOMASTER made better choice than librarian did

| Cases | Category I | (%) | Category II | (%) | Category III | (%) | Category IV | (%) |
|---|---|---|---|---|---|---|---|---|
| Best Gateway Result | 8 | (16) | 21 | (42) | 13 | (26) | 8 | (16) |
| Worst Gateway Result | 5 | (10) | 23 | (46) | 20 | (40) | 2 | (4) |

**Table 3. Consistency in Database Selection by INFOMASTER for the Same Query Among Three Students**

| Query's Subject | Total No. of Queries in This Subject Field | Total No. of Queries with Different Choices (%) | No. of 2 Choices | No. of 3 Choices |
|---|---|---|---|---|
| Agriculture | 11 | 2 (18.2) | 2 | 0 |
| Environmental Science | 2 | 2 (100.0) | 2 | 0 |
| Art & Literature | 3 | 2 (66.7) | 1 | 1 |
| Library Science | 1 | 1 (100.0) | 1 | 0 |
| Education | 6 | 0 (0.0) | 0 | 0 |
| Social Science | 7 | 0 (0.0) | 0 | 0 |
| Computer Science | 1 | 1 (100.0) | 1 | 0 |
| Engineering | 8 | 2 (25.0) | 2 | 0 |
| Materials Science | 8 | 7 (87.5) | 5 | 2 |
| Physicial Science | 3 | 1 (33.3) | 1 | 0 |
| Total Queries | 50 | 18 (36.0%)* | 15 (30.0%)* | 3 (6.0%)* |

Total **Consistency of Database Selection** by INFOMASTER = **64%** ( (50-18)/50 or 1-0.36 )
* The percentages are all based on the total of fifty queries.

**Table 4. The Evaluation of INFOMASTER Database Selection by Students (Inexperienced Searchers of INFOMASTER) (Questionnaire Survey Results)**

| Items | Contents | | Results of Survey | | Notes |
|---|---|---|---|---|---|
| | | | Number | (%) | |
| Evaluation of Use of INFOMASTER | Ease of Use | 1 (Difficult Use) | 1 | 1.3 | |
| | | 2 | 1 | 1.3 | |
| | | 3 | 4 | 5.3 | |
| | | 4 | 12 | 16.0 | |
| | | 5 (Easy Use) | 57 | 76.0 | |
| | Helpfulness in Database Selection | 1 (Not Helpful) | 4 | 5.3 | |
| | | 2 | 3 | 4.0 | |
| | | 3 | 14 | 18.7 | |
| | | 4 | 24 | 32.0 | |
| | | 5 (Helpful) | 30 | 40.0 | |
| Time Used for Searching INFOMASTER (in minutes) | 0 - 15 | | 30 | 40.0 | (Time counted from logon until logoff including two searches.) |
| | 16 - 30 | | 39 | 52.0 | |
| | 31 - 45 | | 4 | 5.3 | |
| | 46 - 60 | | 2 | 2.7 | |
| | > 60 | | 0 | 0 | |

**Appendix. Example of Posting Databases (PD): Database Selection by Librarians and INFOMASTER Operated by Students Compared With Posting Databases (PD)**

(Note: DB = Database; Most databases which librarians or INFOMASTER selected will be involved in Posting Databases (PD). If any database was not involved in PD list, it must be the database with 0 item for the corresponding search query.)

| No. | Search Query | Subject of Search | DBs Selected by Librarian | | DBs Selected by INFOMASTER | | Posting Databases (PD) List | |
|---|---|---|---|---|---|---|---|---|
| | | | DBs' Name | No. of Items | DBs' Name | No. of Items | DBs' Name | No. of Items |
| 14. | Living Realist Sculptors | Art | RILA | 85 | RILA | 85 | RILA | 85 |
| | | | | | RILA | 85 | ART MODERN | 23 |
| | | | | | RILA | 85 | HISTORICAL ABSTRACTS | 1 |
| 15. | Literary Salons in 19th Century France | Literature | MLA | 7 | MLA | 7 | HISTORICAL ABSTRACTS | 12 |
| | | | | | AHCI | 4 | MLA | 7 |
| | | | | | MLA | 7 | AHCI | 4 |
| | | | | | | | SOCA | 1 |
| | | | | | | | LLBA | 1 |
| | | | | | | | AMERICA: HISTORY & LIFE | 1 |
| | | | | | | | RELIGION INDEX | 1 |
| 16. | Reviews of Films by Andrei Tarkovskii | Art (Cinema Studies) | MAGILL'S SURVEY OF CINEMA | 5 | ART INDEX | 6 | NATIONAL NEWSPAPER INDEX | 24 |
| | | | | | NATIONAL NEWSPAPER INDEX | 24 | MAGAZINE INDEX | 22 |
| | | | | | AHCI | 16 | AP NEWS | 17 |
| | | | | | | | AHCI | 16 |
| | | | | | | | UPI NEWS | 16 |
| | | | | | | | MLA | 15 |
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